

Products and systems for the protection and repair of concrete structures — Test methods —

Part 4: Determination of shrinkage and expansion

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British Standard

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National foreword

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Foreword

This document EN 12617-4:2002 has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2002, and conflicting national standards shall be withdrawn at the latest by December 2002.

It was prepared by sub-committee 8 "Products and systems for the protection and repair of concrete structures", the secretariat of which is held by AFNOR.

This European Standard is one of a series dealing with products and systems for the protection and repair of concrete structures.

This European Standard describes two methods for determining the dimensional stability of repair products and systems subject to conditions of drying and immersion. The first method measures the unrestrained shrinkage and expansion, while the second method measures the effects of restraint on the unrestrained shrinkage and expansion.

It is one of a series of inter-related parts dealing with dimensional stability of repair products and systems. The other parts are:

prEN 12617-1, *Products and systems for the protection and repair of concrete structures - Test methods – Part 1: Determination of linear shrinkage.*

prEN 12617-2, *Products and systems for the protection and repair of concrete structures - Test methods – Part 2: Determination of volumetric shrinkage.*

EN 12617-3, *Products and systems for the protection and repair of concrete structures - Test methods - Part 3: Determination of early age linear shrinkage for structural bonding agents.*

Annex A is normative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies a method for measuring the dimensional stability (i.e. the shrinkage and expansion movement) due to changes in the moisture content of hydraulic mortars or concretes (CC) or polymer hydraulic cement mortars or concretes (PCC) as defined in EN 1504-1. Two methods are proposed, namely a procedure for unrestrained movement and a procedure for restrained movement.

The provisions of the standard are applicable to grout, mortar or concrete products or systems with a maximum aggregate size of 10 mm.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 196-1:1994, *Methods of testing cement - Part 1: Determination of strength*.

EN 1015-2, *Methods of test for mortar for masonry – Part 2: Bulk sampling of mortars and preparation of test mortars*.

EN 1504-1, *Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity- Part 1: Definitions*.

EN 1542, *Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off*.

EN 1766, *Products and systems for the protection and repair of concrete structures - Test Methods - Reference concretes for testing*.

prEN 1504-3¹, *Products and systems for the protection and repair of concrete structures - Part 3: Structural and non-structural repair*.

ISO 554, *Standard atmospheres for conditioning and/or testing – Specifications*.

3 Terms and definitions and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 1504-1 apply.

3.2 Symbols

The following list of symbols is used in this standard.

c	is the specific length variation, in % ;
m	is the specific mass change, in % ;
L	is the initial length of test specimen at time of release from mould, in mm ;

¹ Under preparation.

L_g	is the gauge length ($L_g = L$ only for type 2 studs), in mm ;
L_0	is the initial reading in the measuring apparatus, taken after 24 h, in mm ;
ΔL	is the length variation in relation to the initial length, in mm ;
M_0	is the initial mass of the test specimen at time of release from the mould, in g ;
ΔM	is the mass variation in relation to the initial mass, in g.

4 Principle

The shrinkage or expansion determination comprises two methods of test for CC and PCC repair products and systems.

The first method is for measuring the unrestrained linear movement arising from immersion in water (expansion) or drying conditions (shrinkage) of prismatic specimens 40 mm × 40 mm × 160 mm in size from 24 h to 56 days after casting.

The second method is for measuring the loss of adhesion and the tendency to crack, when applied to a 300 mm × 300 mm × 100 mm reference concrete substrate and subjected to immersion in water (expansion) or drying conditions (shrinkage).

5 Apparatus

5.1 Unrestrained movement mould

Moulds, complying with the requirements of 4.5 of EN 196-1:1994 except that there shall be a minimum of three compartments, allowing simultaneous preparation of test specimens. Each compartment shall be provided a hole at the centre of each end face to hold a measurement stud that is to be embedded in the specimen.

5.2 Measurement studs

Studs made of stainless steel, or other hard material that does not react with the mortar. Typical designs for Type 1 recessed stud and Type 2 projecting stud are shown in Figures 1 and 2 respectively.

NOTE The design of the studs and the embedment method need to be compatible with the measuring apparatus used (see 5.3).

5.3 Measuring apparatus

Apparatus used to measure the length of the test specimens. It shall be adjustable to give sufficient length to measure the minimum specimen length ± 5 mm and have an accuracy of measurement of $\pm 0,001$ mm. It shall have suitable fittings to receive the measurement studs (see 5.2).

5.4 Calibration rod

A rod made of invar metal or other material that has a similar coefficient of expansion over the range of test temperatures. The calibration rod shall be (160 ± 1) mm in length and with ends of the same shape as the measurement studs (see 5.2).

NOTE It is recommended that a second identical rod be available to serve as check for wear on the first rod and the seatings of the measuring apparatus (see 5.3), by comparing their apparent lengths at three-monthly intervals.

5.5 Tampers

Tampers consisting of sound, non-absorbent rods, of (38 ± 1) mm and (15 ± 1) mm in diameter and (200 ± 10) mm in length. The tamping face of each rod shall be flat and at right angles to the length of the tamper, the mass of the larger tamper shall be (250 ± 15) g and the smaller tamper (40 ± 5) g.

5.6 Concrete slab test panels

Concrete panels prepared in accordance with the method of EN 1542 with dimensions $300 \text{ mm} \times 300 \text{ mm} \times 100 \text{ mm}$, made using reference concrete to EN 1766 and of a type as specified in prEN 1504-3².

5.7 Standard laboratory climate

Storage room in accordance with the requirements of annex A.

5.8 Mortar mixer

Mixer in accordance with EN 196-1, or forced action pan mixer.

5.9 Compaction tools and equipment

Tools and equipment for compacting repair grouts, mortars and concretes according to EN 196-1 or EN 1015-2.

5.10 Water baths

Baths containing potable water for complete immersing the test specimens at a temperature of (21 ± 2) °C, as defined in annex A.

5.11 Triangular support grid

A grid onto which the specimens are supported in the standard laboratory climate or water bath, to achieve a minimum 5 mm clearance.

6 Procedure for unrestrained movement

6.1 General

Unless specified to the contrary, not less than six prism specimens shall be prepared and tested, from which three specimens shall be used for measuring the average shrinkage and three specimens shall be used for measuring the average swelling.

6.2 Preparation of specimens

All materials shall be conditioned in the standard laboratory climate (see annex A) for a period of not less than 24 h prior to mixing.

Unless otherwise instructed by the manufacturer, use the following mixing technique for preparing the specimens.

For PCC and CC mortar, use the mortar mixer (see 5.8) set to a low speed, pouring the gauging liquid into the bowl and adding the dry ingredients, mixing for a total period of two minutes.

² Under preparation.

Where the manufacturer's instructions preclude use of part bags of material, a forced action pan mixer (see 5.8) or other method recommended by the manufacturer shall be used.

NOTE 1 It has been found that certain types of repair mortar can foam excessively under the action of the mortar mixer specified in EN 196-1. An alternative is to use a forced action pan mixer (see 5.8).

NOTE 2 The air content (see EN 1015-7, pressure method) and the compressive strength and density (see EN 12190) of the CC and PCC mixes should normally be determined to characterise the mortar under test.

If type 1 measuring studs are to be used, these shall be attached to the mould using a bolt that passes through the hole in the centre of each end face and locates on the threaded stud, ensuring the stud is positioned centrally.

If type 2 measuring studs are to be used, these shall be inserted into the holes in the end faces of the moulds so that they are up against the conical part of the hole, in so doing, care shall be taken that the studs are not displaced during specimen preparation.

NOTE 3 To hold the measuring studs securely, the holes of the mould can be filled with a moulding compound into which the studs are pressed, carefully removing any moulding compound expelled.

The repair product or system shall be carefully compacted into the moulds, using the smaller diameter tamper (see 5.5) to work the material around the portion of stud projecting into the mould, thereby ensuring full compaction. The compaction method shall be in accordance with the manufacturer's instructions.

NOTE 4 As there is a risk of breakage during removal of the mould and subsequent handling, it is recommended that additional specimens are cast and tested alongside the minimum number of three specimens.

The repair product or system shall then be cured in the standard laboratory climate (see annex A) for 24 h.

6.3 Initial measurement

6.3.1 General

Before undertaking initial measurement, all measuring equipment (see 5.3 and 5.4) shall be brought to the test temperature for at least 24 h.

After (24 ± 1) h from mixing, the specimens shall be carefully removed from the moulds.

NOTE If retarded, accelerated or expansive products or systems are being tested, the manufacturer's advice should be sought.

Before taking the first measurement, the adhesion of the measuring studs shall be checked. If this is inadequate, either the measuring studs shall be secured with a suitable adhesive or the affected specimens shall be rejected.

The reading on the measuring apparatus (see 5.3) shall first be checked with the calibration rod (see 5.4), using the general measuring technique (see 6.3.2). The specimens shall then be marked with a unique identifier, and then the initial mass (M_0) and the initial length (L) recorded. An initial reading (L_0) shall then be taken on the measuring apparatus (see 6.3.2). After completion of a series of initial measurements, the reading for the calibration rod shall be taken again.

6.3.2 Method of measurement

The position of the specimen in the measuring apparatus shall be the same for each measurement. To ensure this is achieved, an alignment point shall be marked on each specimen at the time of the first reading.

When the calibration rod (see 5.4) or test specimens are rotated about their axis in the measuring apparatus (see 5.3), the reading on the apparatus shall not change by more than $\pm 0,001$ mm. Where excess movement occurs, the measuring apparatus shall be checked for function and the measuring studs in the specimens checked for fixity and cleanliness and the readings repeated.

NOTE Misalignment of the measuring studs in the moulds is one of the most common causes of excess movement when the specimens are rotated.

The measured values shall be read off and stated to the nearest 0,001 mm.

6.4 Storage conditions

6.4.1 General

After the initial measurement, the specimens shall be stored on the triangular grid (see 5.11) which does not restrict swelling or shrinkage movement of the specimen under the test conditions.

6.4.2 Standard drying climate

After demoulding, the specimens shall be stored at a temperature of $(21 \pm 2) ^\circ\text{C}$ and $(60 \pm 10) \% \text{RH}$, as defined in annex A.

To maintain a uniform moisture exchange around the specimen, a spacing between specimens of at least (100 ± 10) mm shall be maintained.

6.4.3 Immersion

After demoulding, the specimens shall be stored under potable water at a temperature of $(21 \pm 2) ^\circ\text{C}$, as defined in annex A.

Before immersion, the measuring studs shall be coated with petroleum jelly.

NOTE A build-up of salts can occur on the measuring studs and the use of petroleum jelly helps to prevent this from occurring.

6.5 Subsequent readings

6.5.1 General

The air temperature in the test room shall be equal to the storage conditions defined in annex A. Wherever possible the measuring equipment and reference specimens should be kept permanently in the test room, otherwise they shall be placed there at least one day before measurements are to be taken.

6.5.2 Preparation

Each specimen shall only be removed from the storage container immediately before measurement. If necessary, any petroleum jelly and adhering foreign matter shall be removed from the measuring studs with a dry leather. In the case of conditioning in water, the specimens shall be dabbed with a moist cloth to remove excess water.

It shall be ensured that the specimens are not handled more than is essential for cleaning the studs and locating in the measuring apparatus, to avoid unnecessary heating by the hands. The time between removal from the storage container and fitting into the measuring equipment shall not exceed 2 min. The actual duration of measurement shall be as short as possible.

The reading on the measuring apparatus (see 5.3) shall first be checked with the calibration rod (see 5.4) and then the length of the specimens recorded using the general measuring technique (see 6.3.2). After completing a series of measurements, the reading for the calibration rod shall be taken again. If a difference is found between the check measurements before and after the measurement of the specimens, the measuring equipment shall be checked (for seating and cleanliness, for example) and the measurement of the specimens shall be repeated.

If, at any specific age, the variation in length of one of a set of three or more test specimens exceeds that of the most comparable test specimen by more than 0,5 mm/m, the reason for this shall be determined (e.g. dust, poor contact, loosening of studs, etc.). If the problem cannot be solved, the test specimen shall be rejected.

After measurement the specimens shall be replaced immediately into the storage container.

6.5.3 Measurement schedule

The frequency of measurement and the test duration will depend upon the purpose of the test.

NOTE Commonly, it is sufficient to measure the shrinkage or swelling after 1, 3, 7, 14, 28 and 56 days from demoulding.

6.6 Calculation

The gauge length (L_g) shall be the specimen length minus 10 mm when using a type 1 measuring stud. The gauge length (L_g) shall be the specimen length when using a type 2 measuring stud.

The change in length shall be calculated in relation to the initial reading (L_o) taken after 24 h. The movement strain shall be expressed as the change in length (L) over the gauge length (L_g), in units of mm/m, expressed to the nearest 0,01 mm/m.

$$\text{Strain} = \frac{L \times 1\,000}{L_g} [\text{mm/m}] \quad (6.1)$$

Alternatively, the strain may be expressed as a percentage, also termed the specific length variation (c).

$$c = \frac{\Delta L \times 100}{L_g} [\%] \quad (6.2)$$

6.7 Recommended additional test

After each measurement of shrinkage or expansion, it is advisable to find the change in mass of the specimen during the test, expressed as the specific mass variation (m). The specimen shall be weighed to the nearest 0,1 g to find the water absorption or water loss. The specific mass variation (m), can then be calculated from the change in mass (M), determined as follows :

$$m = \frac{\Delta M \times 100}{M_o} [\%] \quad (6.3)$$

7 Procedure for restrained movement

7.1 General

Five concrete slab test panels (see 5.6) are required for measuring the restrained movement. Unless specified to the contrary, two specimens shall be tested for shrinkage and two specimens shall be tested for swelling, with the remaining specimen used as a control.

7.2 Preparation of specimens

Five concrete slab test panels (see 5.6) shall be prepared by storing under the standard laboratory climate (see annex A) until they are at least six-months old to ensure shrinkage is effectively complete. The repair product or system shall then be applied to the concrete slab test panels in accordance with the procedure of EN 1542. The full 28 day cure of the CC or PCC mortar shall take place in accordance with the requirements of annex A.

At the end of the 28 day cure period, the five specimens shall be inspected for evidence of cracking or delamination and any such defects recorded.

One specimen shall be tested to determine the control values for pull-off strength after 28 days in accordance with EN 1542.

7.3 Storage Conditions

For determination of restrained drying shrinkage, two test specimens shall be stored at a temperature of $(21 \pm 2) ^\circ\text{C}$ and $(60 \pm 10) \% \text{RH}$ for 56 days, as defined in A.2.1.

To maintain a uniform moisture exchange around the specimen, a spacing between specimens of at least $(100 \pm 10) \text{mm}$ shall be maintained.

For determination of restrained expansion, two test specimens shall be placed in the water bath (see 5.10) for 56 days at a temperature of $(21 \pm 2) ^\circ\text{C}$ under, as defined for wet conditioning as defined in A.2.2.

7.4 Inspection and testing

Upon completion of the storage period (see 7.3), the test specimens shall be inspected for evidence of cracking or delamination and any such defects recorded. The specimens shall then be tested to find the pull-off bond strength in accordance with EN 1542.

NOTE Measurement of crack width can be used to quantify the severity of any cracking that may occur. Photographs can be beneficial to record the defects.

8 Test report

The test report shall include the following information:

- a) a reference to the test method standard;
- b) name and address of the test laboratory;
- c) identification number and date of the test;
- d) name and address of the manufacturer or supplier of the product;
- e) name and identification marks or batch number of the product;
- f) date of supply of the product;
- g) date of preparation of the test specimens and any deviation from the prescribed method of preparation;
- h) conditions of storage of prepared specimens prior to test;
- i) date of test and details of the test equipment used, including the make, type and capacity and the calibration details or the identification number of the apparatus, specifically:

For the unrestrained shrinkage or expansion test:

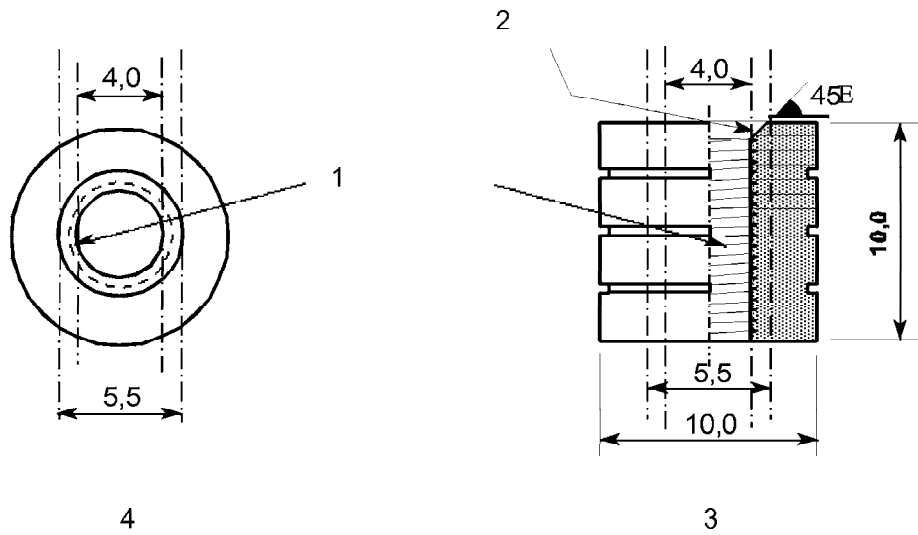
- i) type of test measuring apparatus used;
- ii) test schedule;
- iii) individual values and mean values of the absolute changes in length, in mm, to the nearest 0,01 mm;
- iv) gauge length;
- v) mean values of relative changes in length, in mm/m to the nearest 0,01 mm/m;

- vi) if applicable, individual and mean values of the changes in mass, stated to the nearest 0,1 g;
- vii) if required, individual specific weight variations and mean values at each specific age to the nearest 0,1 %.

For the restrained shrinkage or expansion test:

- i) the diameter, thickness and the material of the dolly used and the type of adhesive;
 - ii) a description of the pull-off test equipment, stating the make, type, load capacity and measurement range;
 - iii) the thickness of the applied repair material;
 - iv) the failure load and the mean diameter for each test location;
 - v) the individual tensile bond strength test results, and the mean result, both before and after conditioning;
 - vi) the type of failure for each location;
 - vii) any anomalies or points of note recorded during testing;
 - viii) visual evidence of cracking or delamination of the test specimen.
- j) the test results;
 - k) precision data;
 - l) date of test report and signature.

Dimensions in millimetres

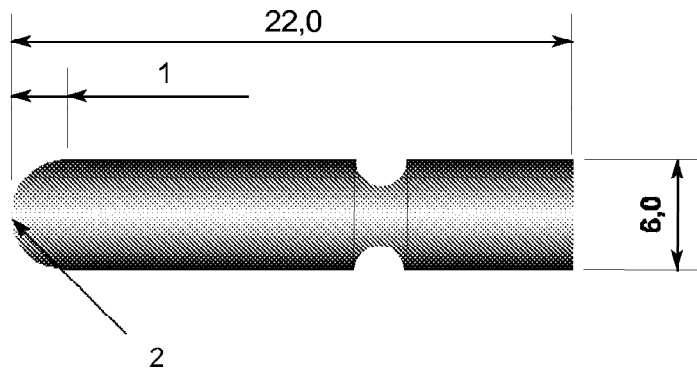


Key

- 1 Threaded internal shaft, 4,0 mm dia.
- 2 Seating for measuring apparatus
- 3 Section
- 4 Top view

Figure 1 — Type 1 recessed stud

Dimensions in millimetres



Key

- 1 3,0 radius
- 2 Spherical end, smooth finish

Figure 2 — Type 2 projection stud

Annex A (normative)

Summary of temperatures and humidities for the curing, conditioning and testing of repair products and systems

A.1 Curing

A.1.1 CC (grouts, mortars and concretes)

- Prepare as EN 196-1, cover in film for 24 h ;
- demould after 24 h ;
- cure under water at (21 ± 2) °C for 27 d.

A.1.2 PCC (grouts, mortars and concretes)

- Prepare as EN 196-1, cover in film for 24 h ;
- demould after 24 h and wrap in film for 48 h ;
- unwrap and cure for 25 d in a standard laboratory climate of (21 ± 2) °C and (60 ± 10) % RH.

A.1.3 PC (grouts, mortars and concretes)

- Prepare as ISO 554 ;
- cure for 7 d at (21 ± 2) °C and (60 ± 10) % RH.

A.2 Conditioning and testing

For specific applications, the following requirements apply :

A.2.1 Standard laboratory climate (dry conditioning)

- Take from the curing/storage environment and condition for 7 d in a standard laboratory climate of (21 ± 2) °C and (60 ± 10) % RH.

A.2.2 Wet Conditioning

- Immerse for 48 h at (21 ± 2) °C, or for CC take directly for test after 28 d of immersion ;
- remove all surface water by standing upright for 30 min before using for tests.

Bibliography

EN 12190, *Products and systems for the protection and repair of concrete structures - Test Methods - Compressive Strength.*

EN 1015-7, *Methods of test for mortar for masonry - Part 7: Determination of air content of fresh mortar.*

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